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MONTE CARLO EVALUATION OF PASSIVE NMIS FOR ASSAY OF PLUTONIUM IN SHIELDED CONTAINERS

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ABSTRACT

Preliminary Monte Carlo simulations have demonstrated that passive Nuclear Materials Identification System (NMIS) measurements can be used to determine the mass of Pu in AT400-R containers with measurement times as short as a few minutes. The sensitivity of the proposed detectors to gamma rays should enhance this measurement method because the gamma rays from fission, induced or spontaneous, escape this container more easily than neutrons. In these calculations, the container contained two Pu spheres with mass varying between 0.5 and 2 Kg with ~6 wt% ^{240}Pu.

1. INTRODUCTION

This paper summarizes a preliminary assessment of the use of the Nuclear Material Identification System (NMIS)[1] for nondestructive assay of the contents of AT400-R storage containers used at the Mayak storage facility. The primary tool for this assessment is a combined neutron-gamma ray transport code MCNP-DSP (Refs. 2, 3, and 4) which calculates directly all the signatures measured by the NMIS in both passive and active modes. These calculations are routinely used for planning and interpreting measurements. An evaluation of the NMIS as applied to Pu metal spheres shows how the signatures depend on fissile mass.

2. PASSIVE NMIS FOR PU ASSAY

NMIS in the passive mode has been shown to be very sensitive to Pu mass in blind tests for DSWA at Los Alamos National Laboratory (LANL) (Ref. 5) in August 1997 and for template measurements at Pantex in December 1997. NMIS correlations for passive measurements depend on the neutrons from spontaneous fission of ^{240}Pu and induced fission of ^{239}Pu. To obtain the ^{239}Pu mass, the ratio of ^{239}Pu to ^{240}Pu must be known. Calculations for a variety of Pu masses with 6 wt% of ^{240}Pu were performed to investigate sensitivity of the measured signatures to fissile mass. Calibration standards could be used to determine the Pu mass assuming isotopic compositions are known. Again, the cross correlation between detectors was the only signature utilized in these simulations.

2.1 DEPENDENCE OF NMIS SIGNATURE ON PU MASS

Passive correlation signatures from NMIS can be used for Pu mass determination. The time distribution of counts in one detector after a count in another detector is measured. For second order correlations this is the temporal distribution of doubles. The integral of correlated time distribution is related to the number of coincidences counts in a multiplicity measurement.[6] Obviously, the correlation functions have additional information that is not available with only multiplicity data. Consequently, NMIS also performs passive multiplicity counting in the same way as commercial multiplicity counters with both event-triggered and randomly triggered time windows. However, the data is processed as in 1 GHz shift register. Because the time window is much shorter than that for conventional multiplicity counters (512 nsec vs 64 μsec), the number of accidental coincident counts from NMIS may be much less than for conventional multiplicity counting that are commonly used for Pu mass determinations.

Many measurements using Cf sources as a surrogate for Pu have shown that the correlation function (temporal distribution of doubles) depends on spontaneous fission rate. One such plot is given in Fig. 1 where the Cf source intensity was increased in four steps. The signatures depend on source fission rate or mass. The same dependency has been shown for Pu mass in plutonium assemblies. In this analysis the dependence of the cross correlation between a pair of the detectors on Pu mass was demonstrated.

2.2 DETECTOR – AT400R CONTAINER CONFIGURATION

The configuration of the AT400-R container (side view) used in these calculations is given in Fig. 2. A top view of the calculation model with the detectors in place is shown in Fig. 3. The Pu spheres were centered in the 10.38-cm diameter spherical cavities and held in position by an Al hemispherical shell of thickness to center the Pu spheres. The AT400-R container was surrounded by four large plastic scintillation detectors that essentially formed a box with inside dimensions of 50 cm. Such large detectors have been used at ORNL for other measurements. This arrangement surrounds the container on all sides with plastic scintillation detectors.

2.3 VARIATION OF PU MASS

To investigate the sensitivity to Pu mass five calculations were performed for spheres of 2, 1.5, and 1.0 and 0.5 kg of delta phase Pu with 1 wt% gallium and 6 wt% ^{240}Pu. In one calculation, sphere masses were mixed (i.e., one 2-kg and one 1.5-kg sphere). These variations of Pu mass were evaluated to establish sensitivity to Pu mass. The covariance functions between a pair of these large plastic scintillation detectors on opposite sides of the container are plotted in Fig. 4 for all cases. These covariance functions are the temporal distributions of coincident counts (doublets) and are proportional to Pu mass. The coincident gamma-ray signatures are primarily at time 0, (i.e. two gamma rays from fission each reach the detectors with small flight time differences).

PASSIVE NMIS MEASUREMENTS SCALE DIRECTLY WITH SPONTANEOUS FISSION RATE

- Passive NMIS measurements of four Cf−252 spontaneous fission sources of nearly identical mass

Passive Coincidence Distribution

Area Under Distribution vs Cf−252 mass

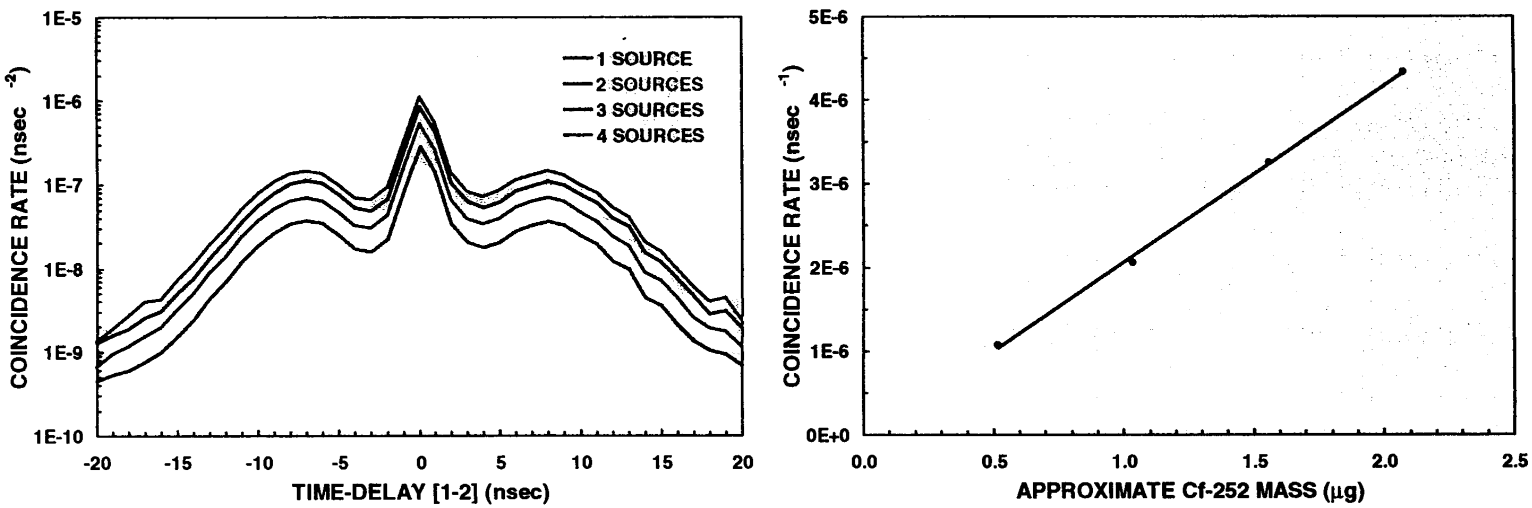

Fig. 1. Passive NMIS measurements scale directly with spontaneous fission rate.

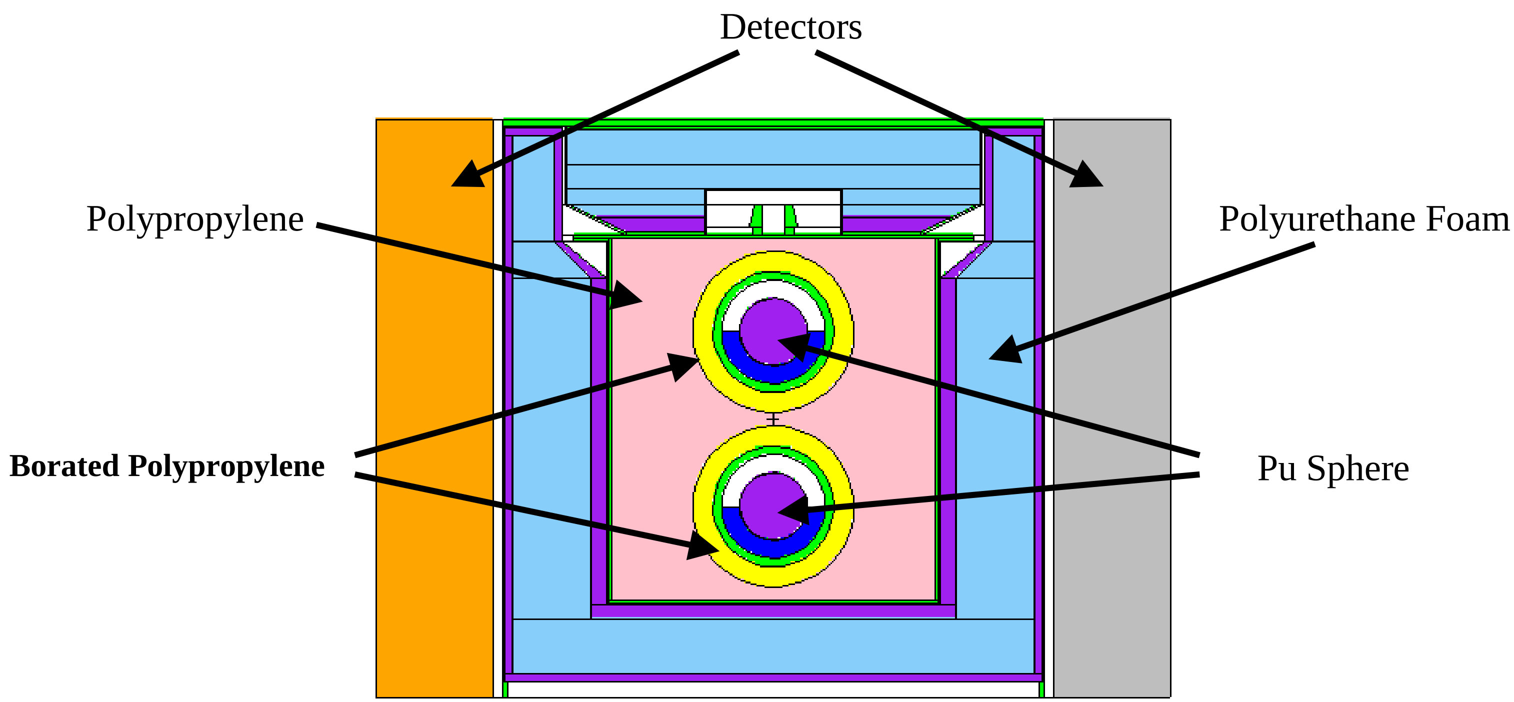

Fig. 2. Passive NMIS simulation model (side view cut through center of Pu metal sphere).

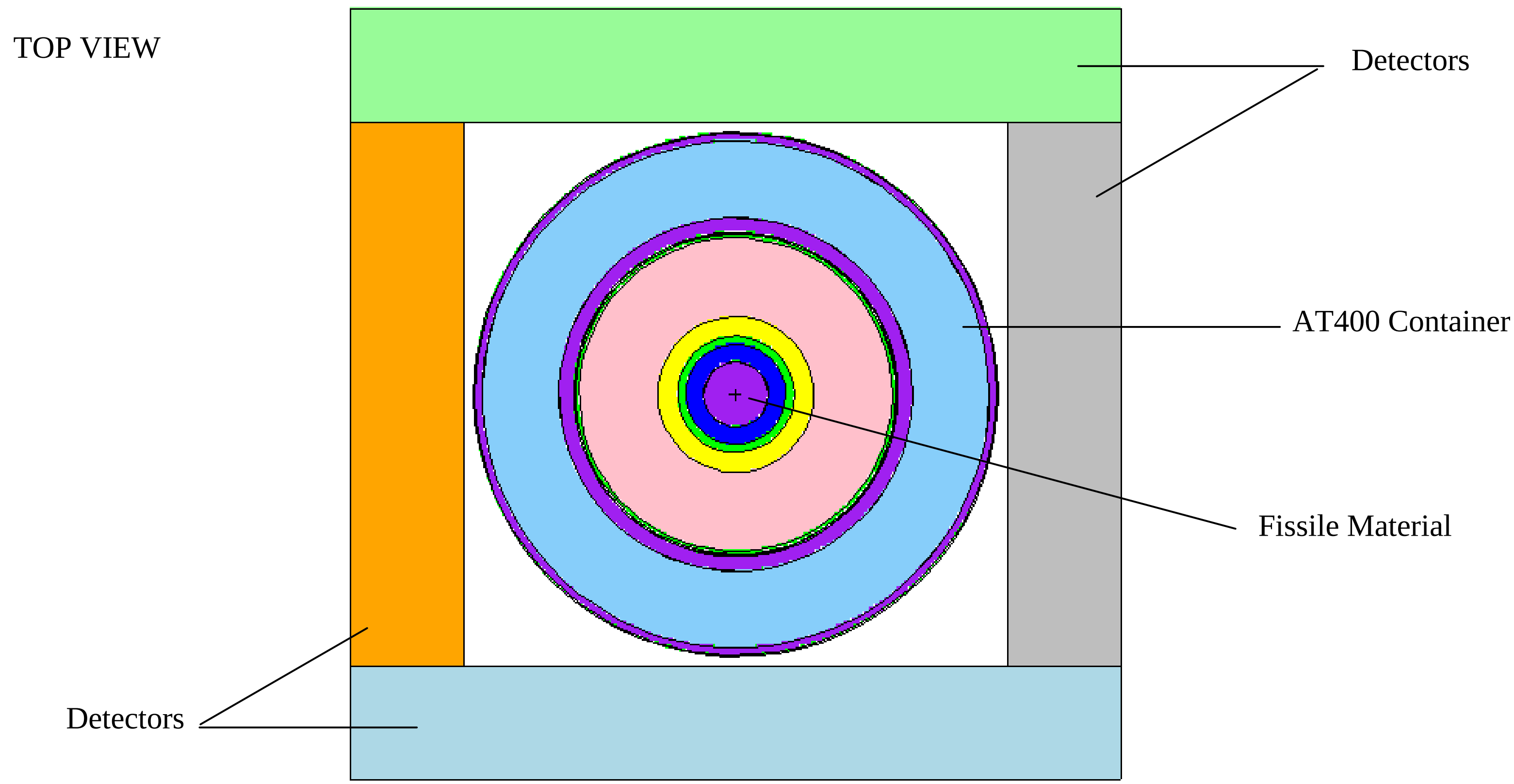

Fig. 3. Passive NMIS simulation model (top view cut through center of Pu metal sphere).

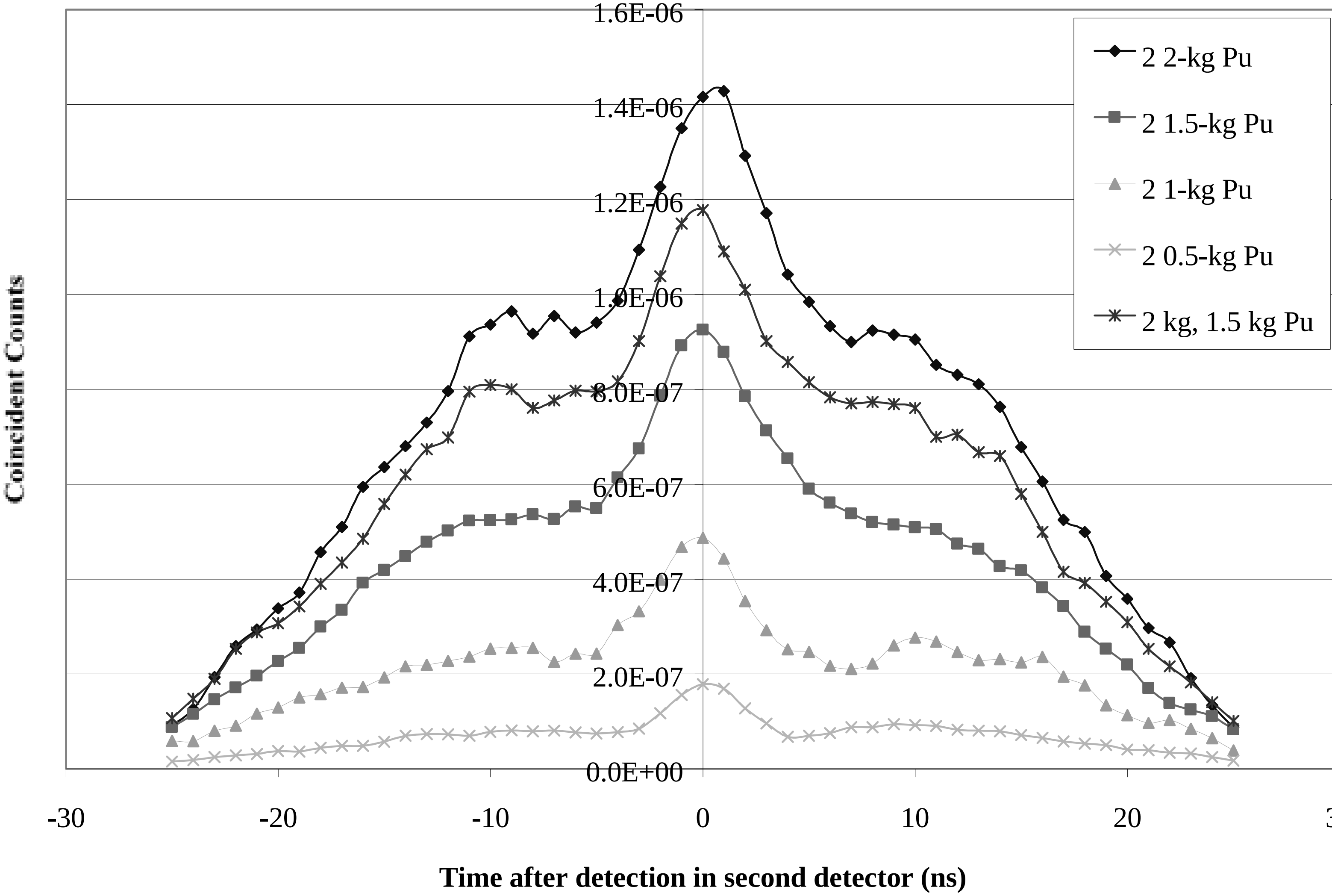

Fig. 4. Time distribution of coincidence counts between a pair of detectors on opposite sides of the container.

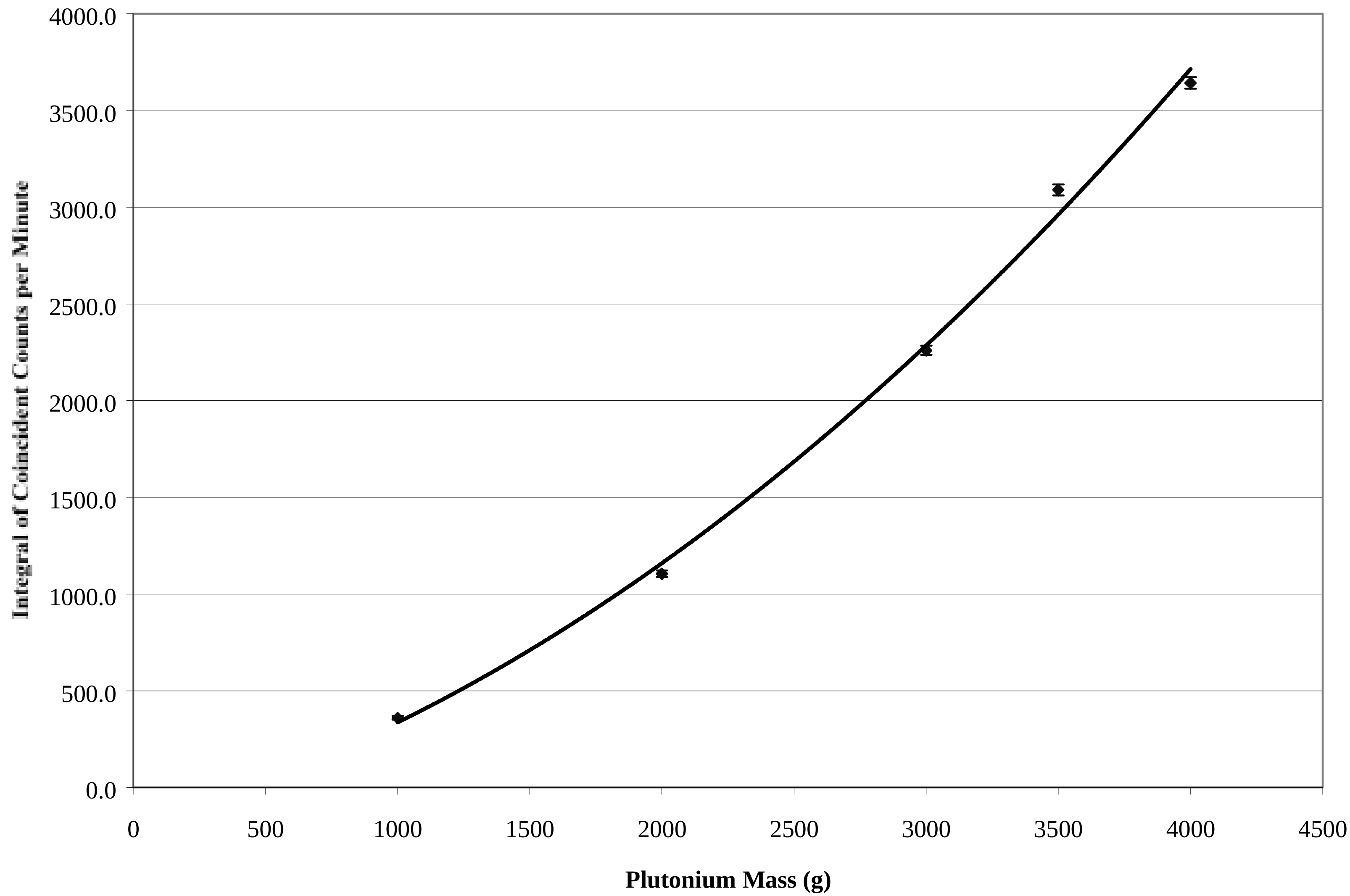

Fig. 5. Total coincident counts vs Pu mass in an AT400R container.

The integrals of these covariance functions are the total number of coincident counts and are plotted as a function of Pu mass in Fig. 5. These calculations represent 900000 spontaneous fission events of ^{240}Pu and thus would correspond to a measurement time of ~1.0 min. for the 2-kg spheres. For the case of 2 kg spheres, the doublet count rate was ~4,000 per minute so 10,000 doubles could be obtained in a few minutes. Of course to obtain Pu mass, Pu isotopics are required. Again many other NMIS signatures such as multiplicities[6] could also be utilized but were not evaluated in this study.

3. CONCLUSIONS

These calculations have shown that passive NMIS measurements (no Cf source) can determine the mass of Pu in AT400-R containers with short measurement times (a few minutes) with large plastic scintillation detectors around the container. This assumes that the plutonium isotopics are known or can be measured using gamma rays spectroscopy and that standards are available to calibrate the measured covariance signatures. Other higher-order NMIS signatures may have advantages over other methods because prompt gamma rays from fission more readily escape the container and can be detected.

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